



GSFC · 2015

Thermal Hardware for the Thermal Analyst

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Reason for This Course

- There are 3 parts to Thermal Engineering:
 1. Thermal Analysis
 2. Thermal hardware installation
 3. Thermal Vacuum Testing
- But many times Analysts are not involved in #2.

Course Outline

- MLI Blanketing Theory 101
- MLI blanketing installation
- Temperature Measurements
- Heaters and Thermostats
- Optical coatings (Paints and tapes)
- Propulsion Systems (tanks, lines, and thrusters)

MLI blanketing 101

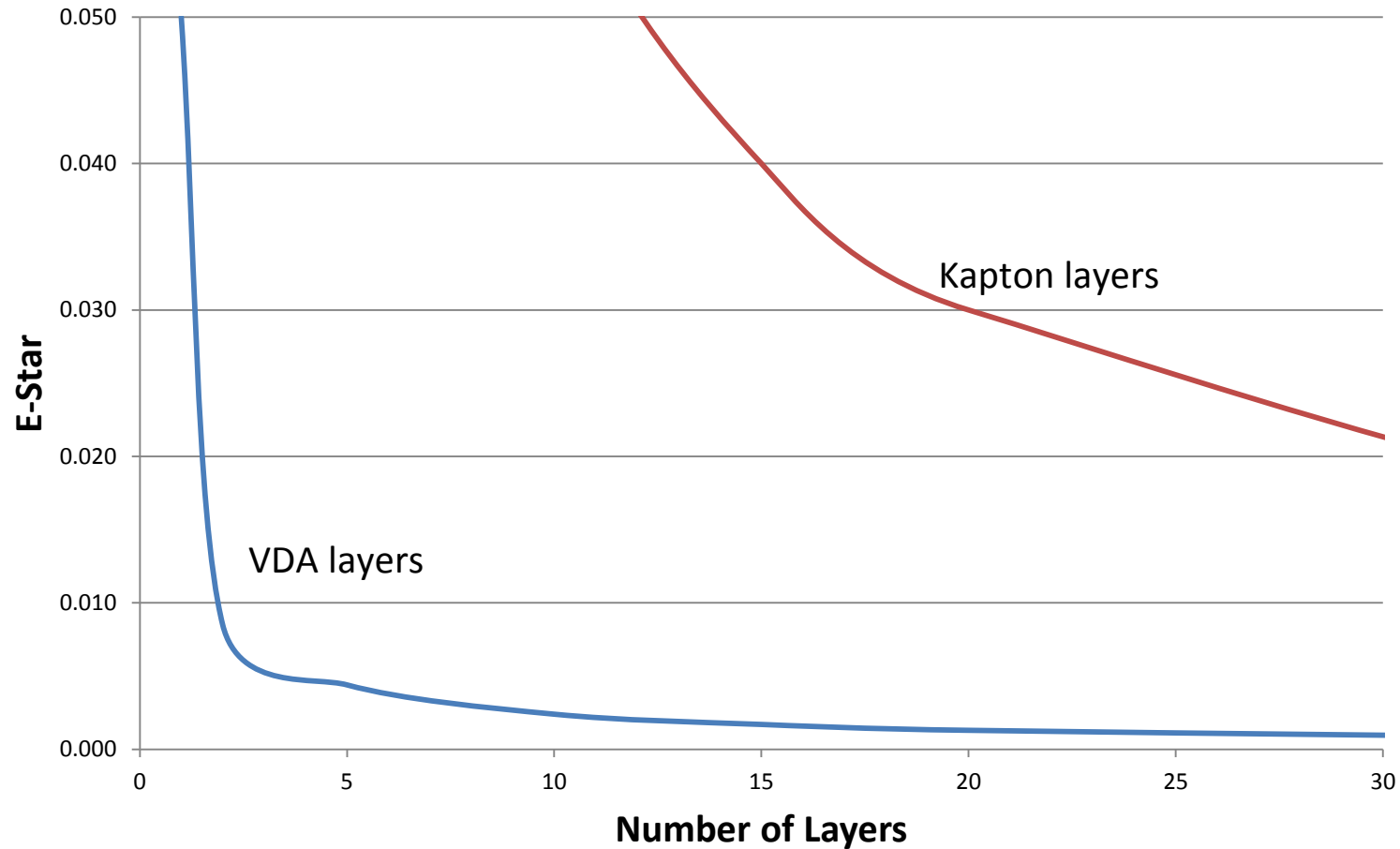
Analyst:

“The actual MLI doesn’t look like what’s in my Thermal Model”

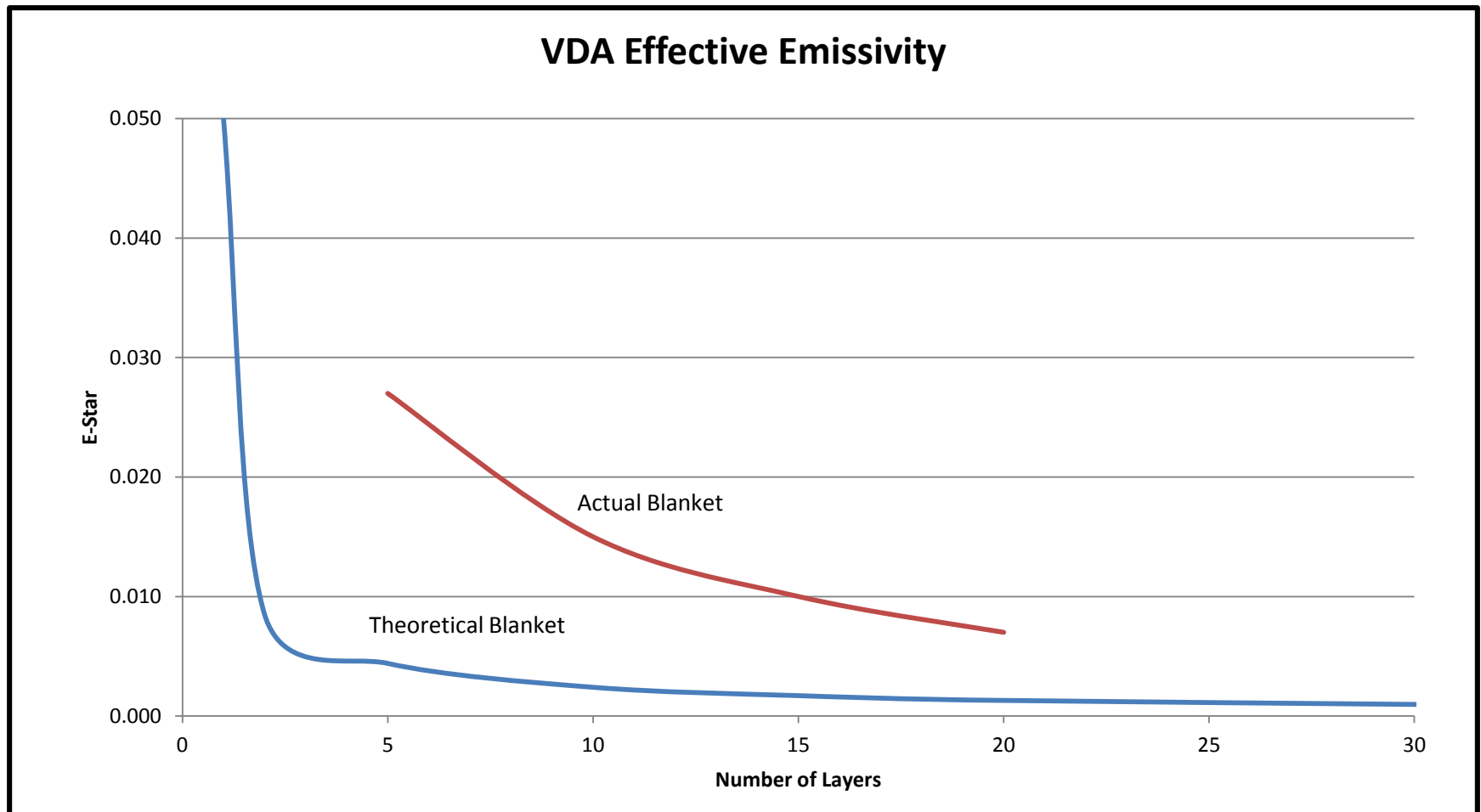
Blanket Tech:

“David, can you help me out? The Thermal Analyst
can’t tell me what he wants”

Theoretical Blanket Effective Emissivity



Actual MLI Blanket



What affects MLI blanket ϵ^* ?

- Penetrations
- Ground Straps
- Crinkling
- Stitching
- Vents
- Separator layers
- Tightness
- Cryogenic Temperatures
- Atmospheric pressure

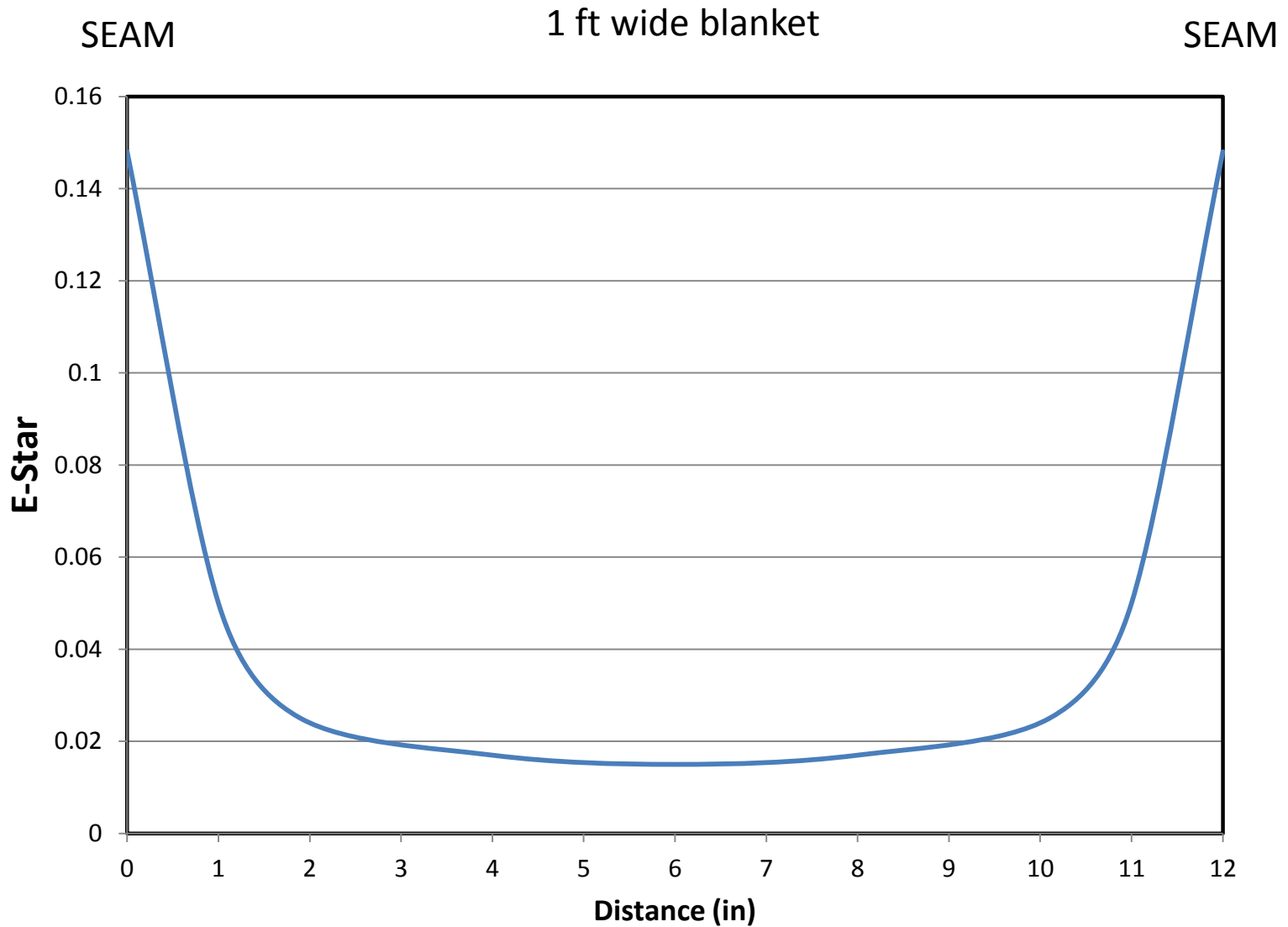
What affects Optical Properties?

- Emissivity usually not effected. Solar Absorptance will be with age.
- Atomic oxygen effects outer layer
 - Silver Teflon needs to be 10 mil instead of 5 mil thick in LEO
- Alpha increases with age (BOL vs. EOL)

Touching Layers = Bad

- 1 ft² blanket covering 30°C surface:
 - Good MLI blanket design = 1.2 watts lost
 - Smashed blanket = 38 watts lost

Stitching Effects

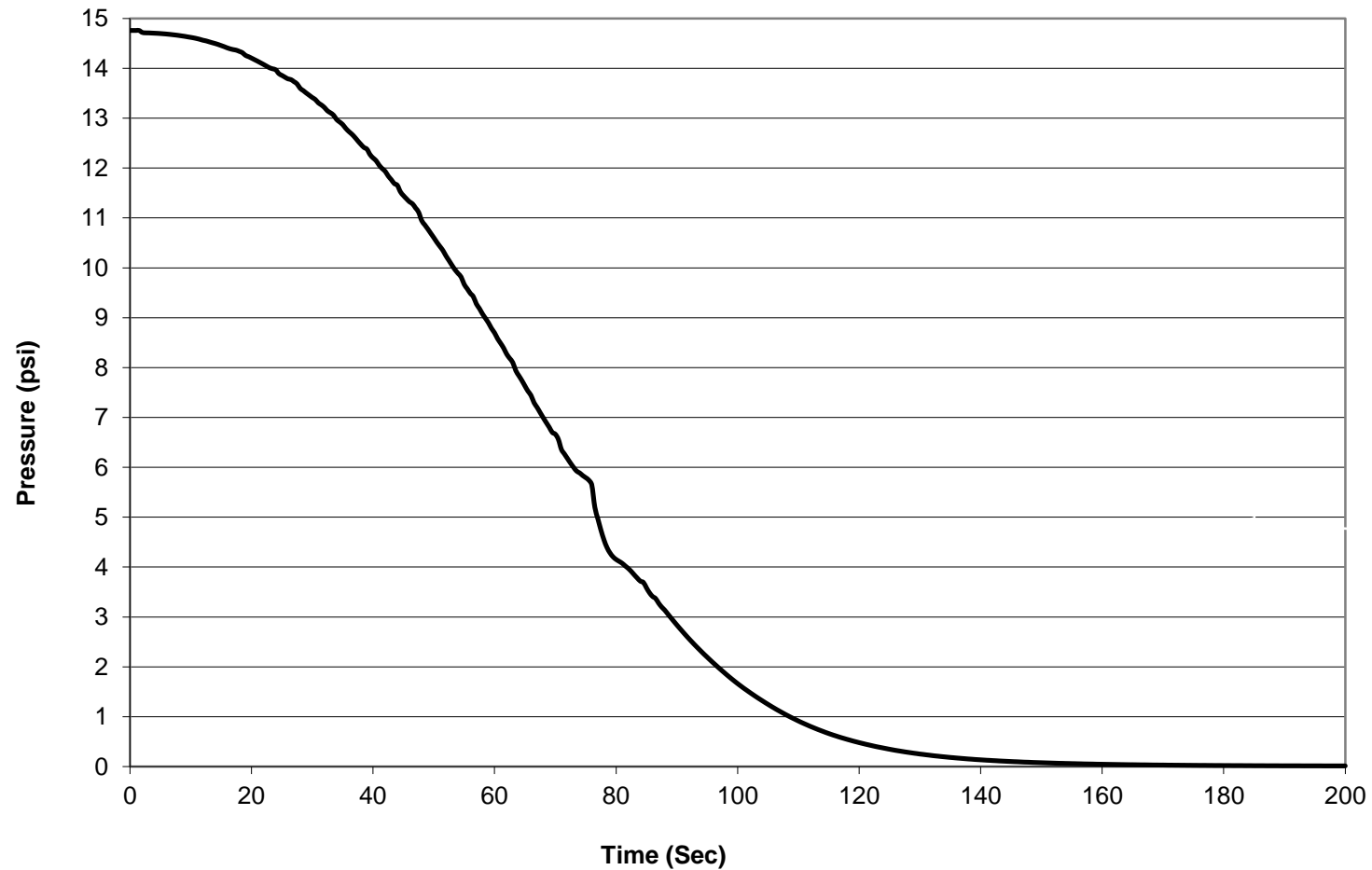


Blankets Vent or Blow Up

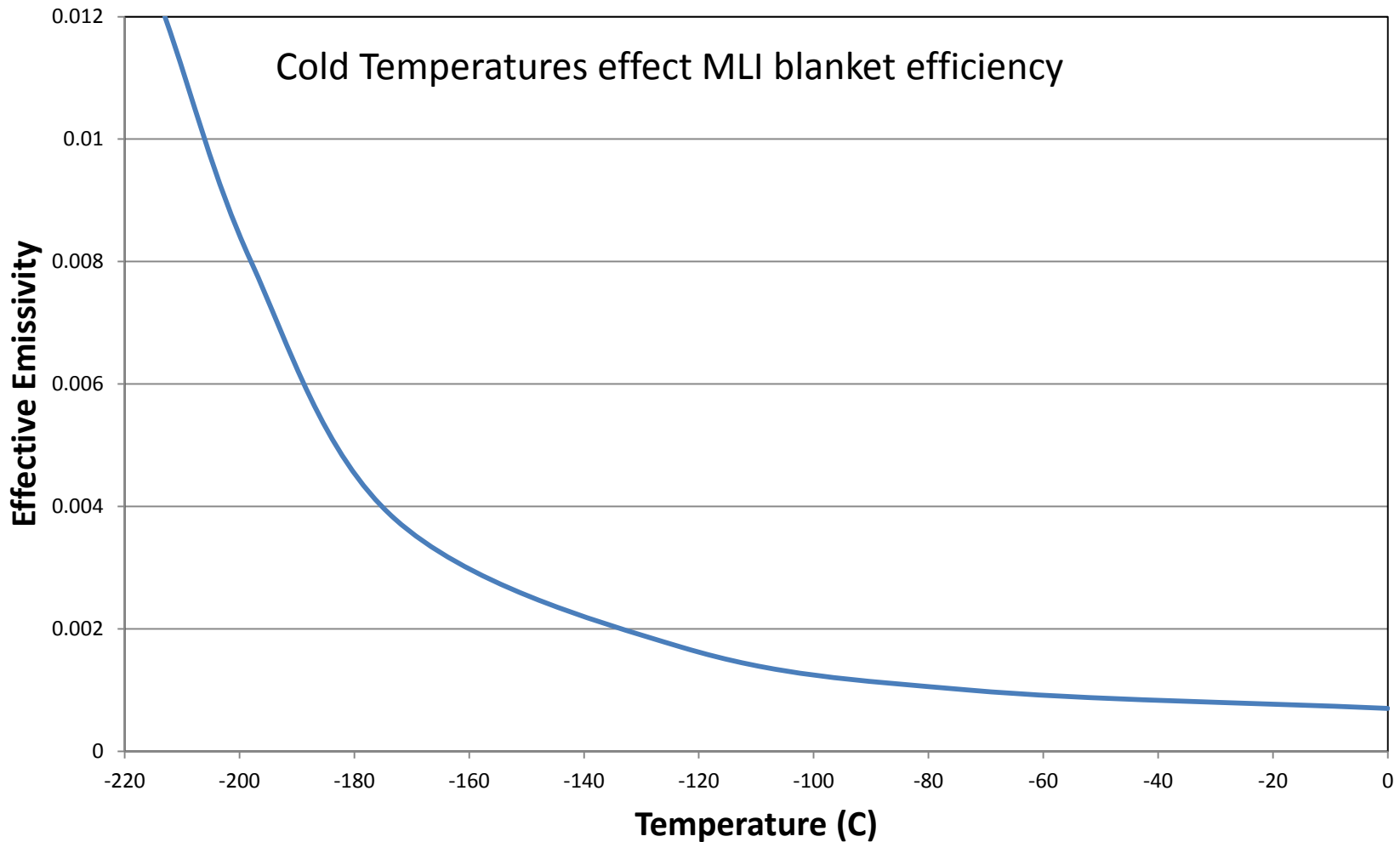
- Air Pressure on ground
 - 14.7 psi
 - 2117 lbs per square foot.
 - But pressure in Space = 0 psi.
- Blankets usually go from Ground to Space (or inside T/V chamber)
 - Air around MLI goes from 14.7 psi -> 0.
- MLI Blankets can only handle 0.1 psi (14.4 lbs per square foot).
- Venting needed:
 - Between MLI layers (or risk blowing up)
 - Between MLI and underlying metal (or risk blowing off surface)
 - Eliminate Gas conduction

Generic Launch Pressure

Inside Fairing

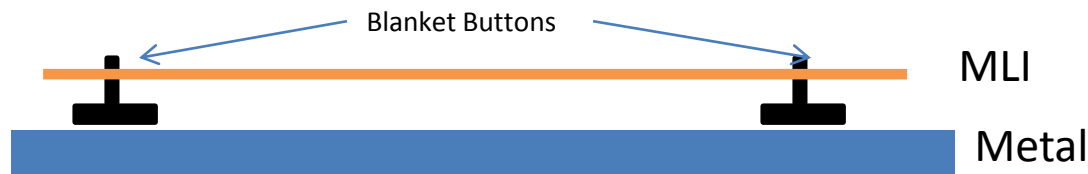


Cryogenic Temperatures

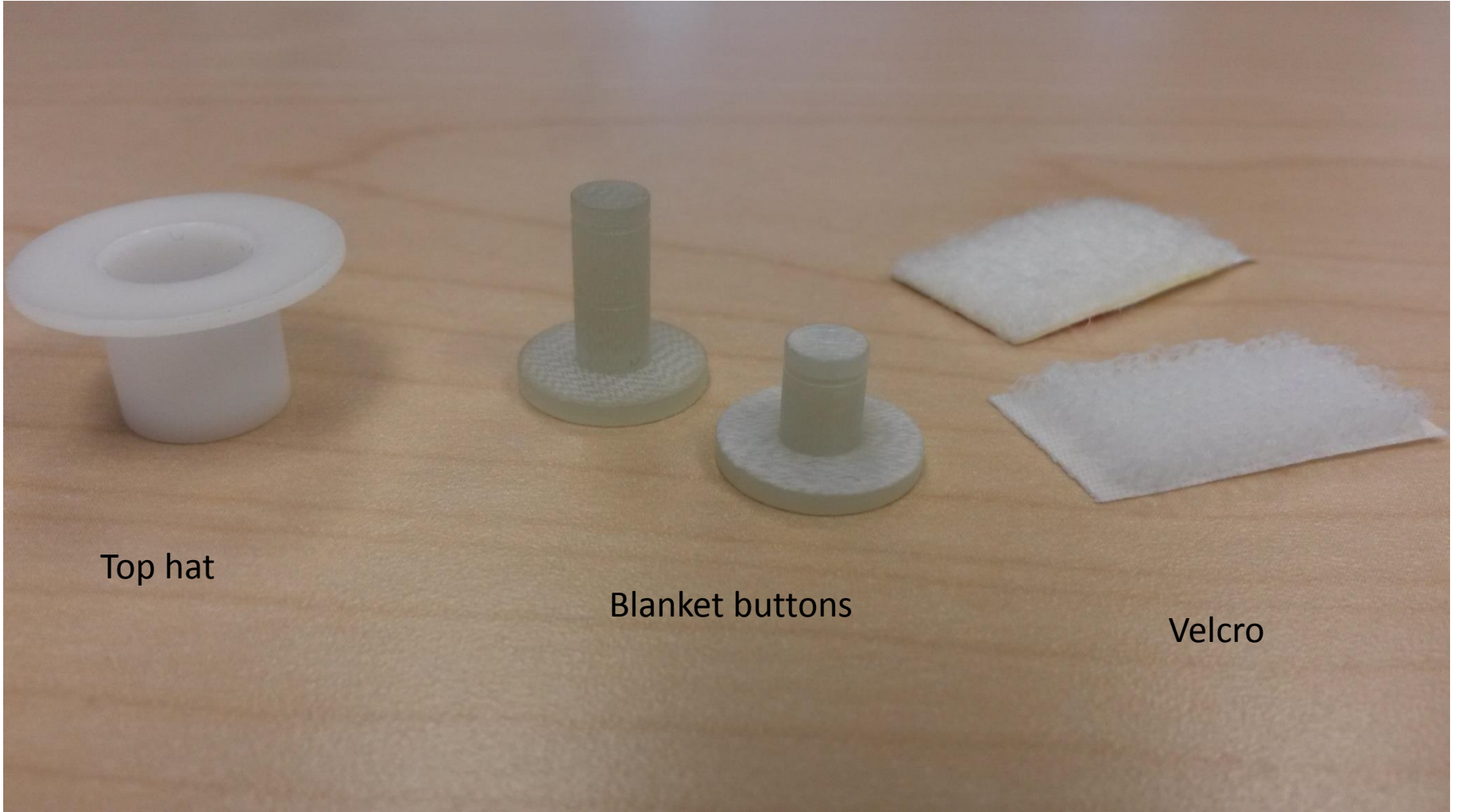


Things Grow and Shrink

- Coefficient of Thermal Expansion
 - Things grow bigger when hot
 - Things shrink when cold
 - Aluminum shrinks/grows a lot compared to Kapton
 - $CTE = 0.000026 \text{ in/in } ^\circ\text{C}$
 - 72 inch piece, from -20°C to $+40^\circ\text{C}$ grows $1/8''$



Blanket Buttons, Etc...



Top hat

Blanket buttons

Velcro

ClickBonds

(For heavier or thicker blankets)



Bonding techniques

- Buttons, Thermistors, Thermostats typically bonded with Stycast 2850FT Cat 9
 - Small bondline, so thermal resistance is low.
- Polymerics license required for bonding Flight hardware.
- Surface preparation is key to a good bond:
 - Clean surfaces
 - Abrade surfaces with sandpaper
 - Vacuum, then clean surface again
 - Hold down with Kapton until epoxy dries overnight.
 - Think about how to handle vertical surfaces!

Thermostats

- Typically bought from Honeywell.
- Type 700 is typical thermostat style

Style 701 (standard)



Style 717 (Prop lines)



Heaters

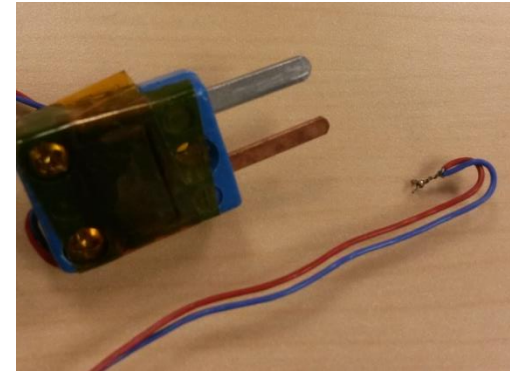
- Kapton Thermofoil Heaters
- Applied with 3M Y966 Acrylic Adhesive
 - Low outgassing
 - Y966 adhesive good to about +100°C
 - Bond with Stycast Epoxy if hotter than +100°C, or watt density higher than 3.5 W/in²
 - Overtaped with 3M 425 aluminum tape to help spread out heat.



Temperature Measuring

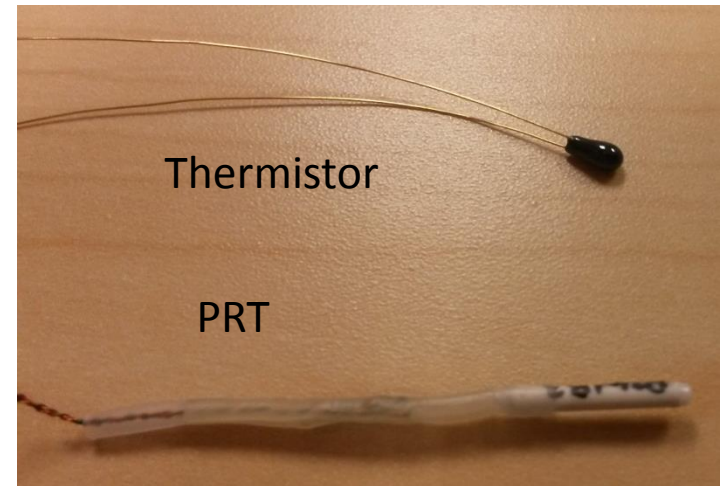
- Thermocouple

- Cheap and easy. Voltage vs. Temperature
 - Remove after T/V testing or flyaway (snip and ground).
 - Type T or Type K. Make sure which one you are using!
 - Attach with 3M 425 Aluminum Tape



- Thermistor

- Non linear Ω vs. Temperature (negative slope)
- Resistances 2252 Ω , 5K, 10K, etc...



- PRT

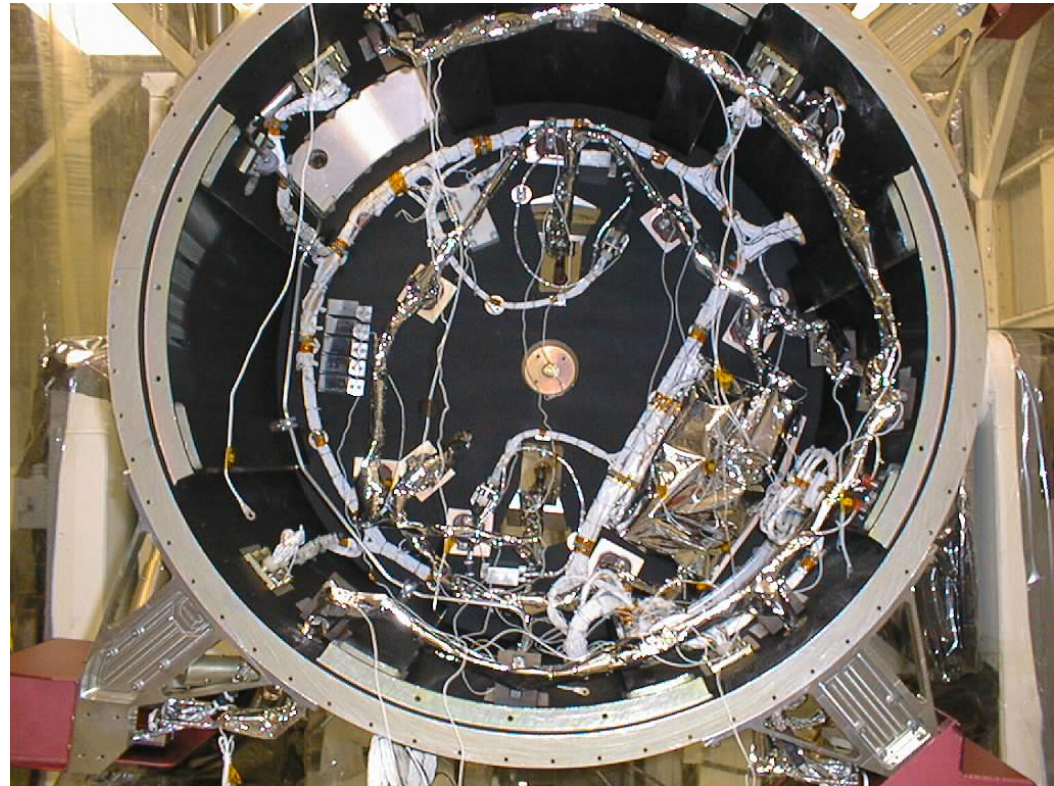
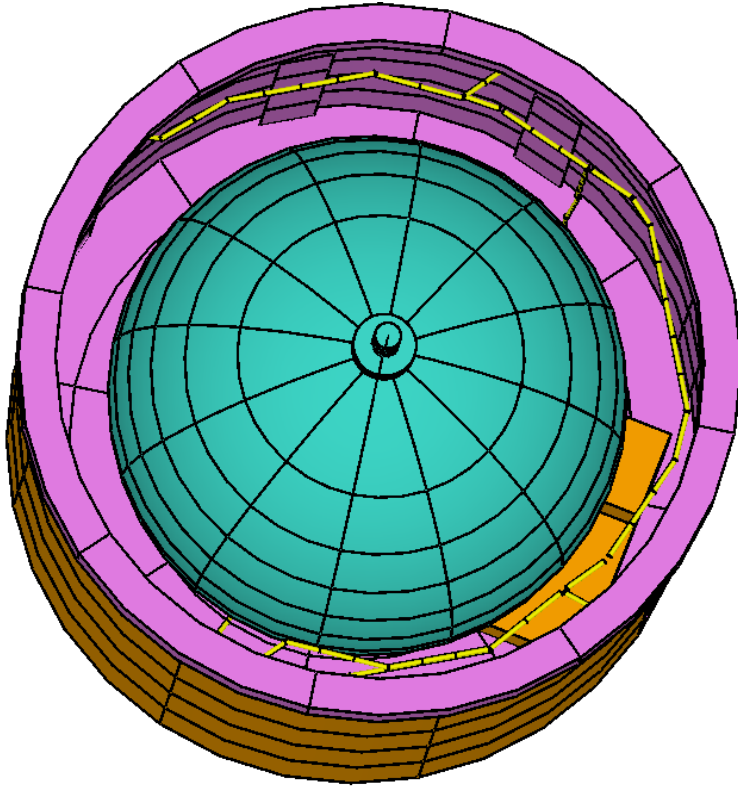
- Very linear Ω vs. Temperature (positive slope)
- Usually used for high or low (cryogenic) temperature.
- 4 wire variety enhances accuracy if needed (usually cryogenic). Removes resistance of leads.
- Resistances usually 100 Ω

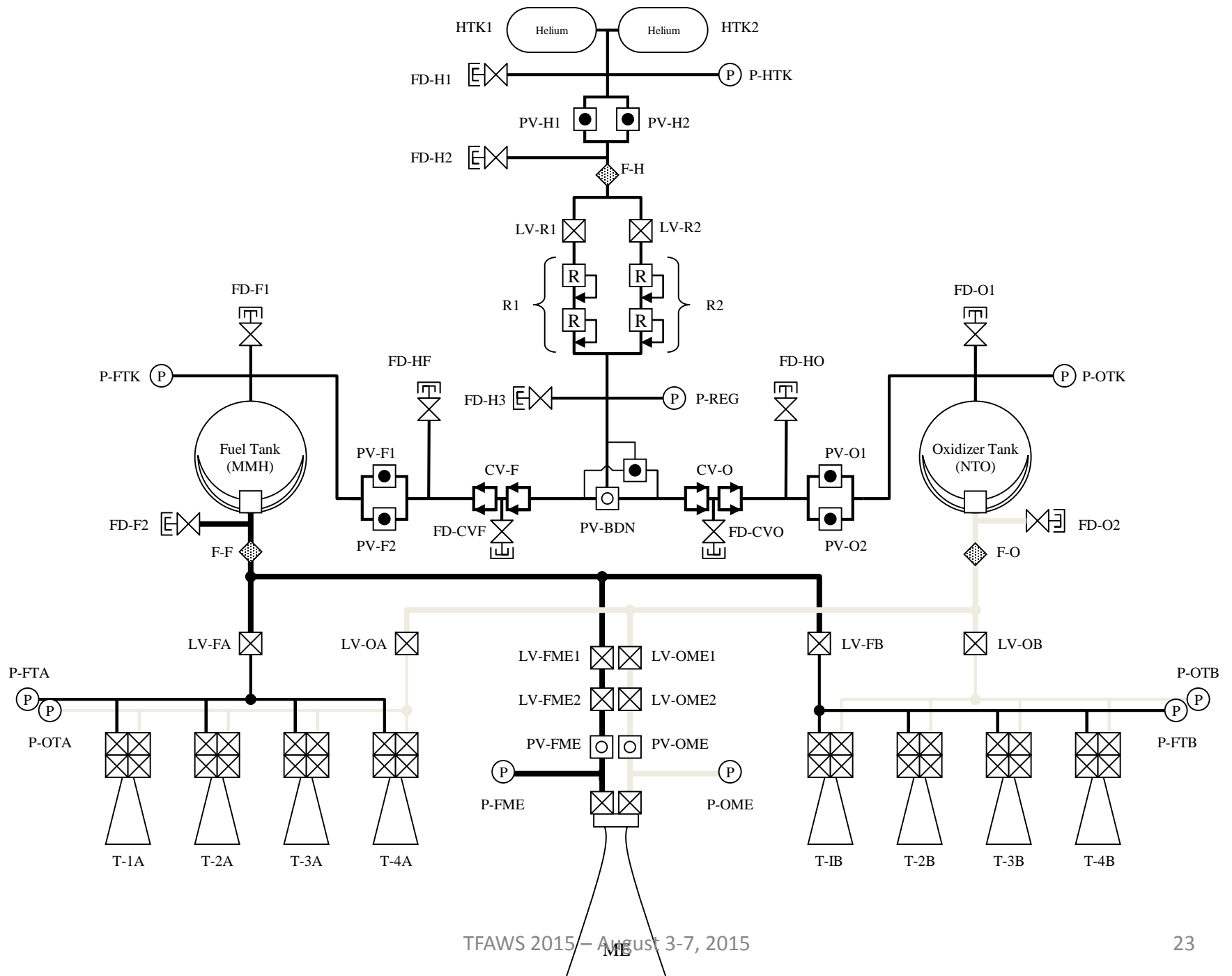
Thermal Enhancement

- Nusil CV-2946
 - 2-part material which needs to be mixed beforehand and degassed.
 - Stored in a freezer or hardens in an hour
 - Use Miller-Stephenson MS-143H as a release agent if needed. Teflon particles. Apply 3 layers.
- Arathane
 - mixed with 30-40% Boron Nitride also good.
 - Cabasil makes it thick.



Propulsion Systems





Analyst vs. Hardware

- **Analyst:**

1. SINDA model has heaters on all nodes of a prop line.
2. Use CALL HEATER subroutine for thermostat cycling.
3. Use e^* of 0.05 for MLI

- **Hardware:**

1. Install Thermostats on Saddle Blocks. Pot terminals if necessary
Or buy 717 style Honeywell Thermostats.
2. Install thermostats/Saddle blocks on Prop Lines with Nusil and zip ties.
3. Wrap spiral Kapton heater around line
4. Hold down with 1 layer of 3M 425 Aluminum tape.
5. Apply 2nd layer of Aluminum tape
6. Add Thermocouple for T/V testing.
7. Wire everything up
8. Wrap MLI around pipe
9. Ground the MLI with its Ground Strap to structure

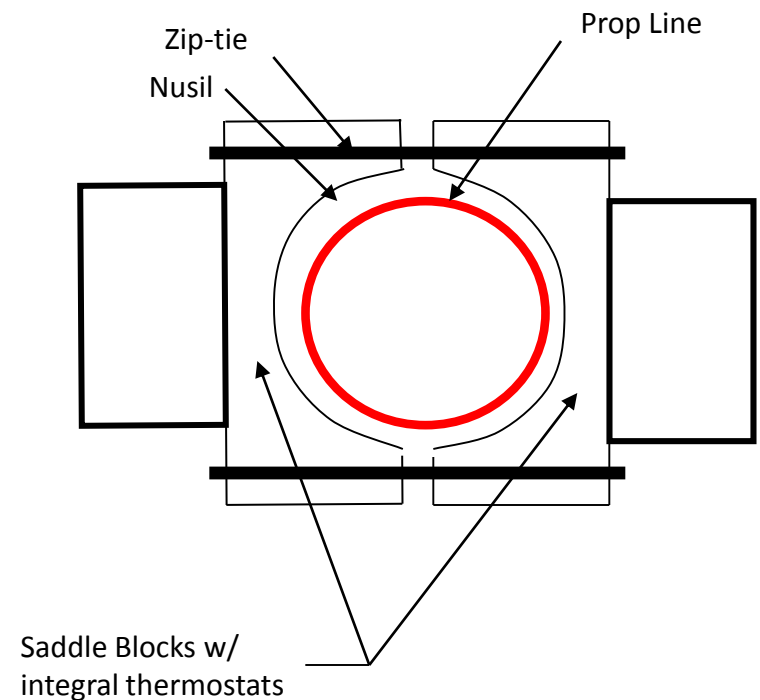
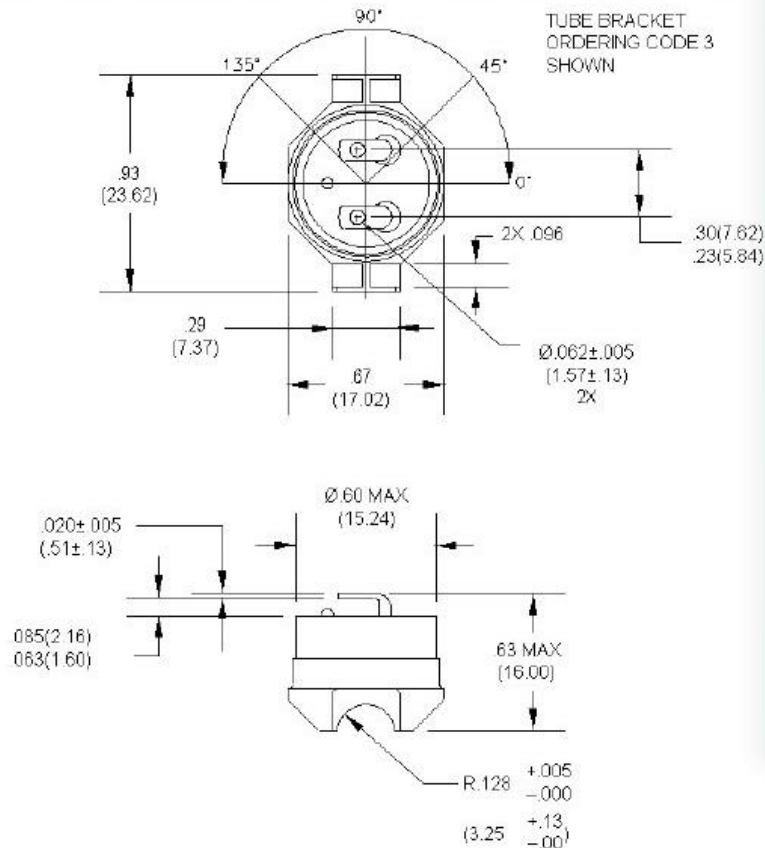
Spiral Kapton Heaters for Prop Lines



Prop Line Tstats on Saddle Blocks

Honeywell Model Style 717

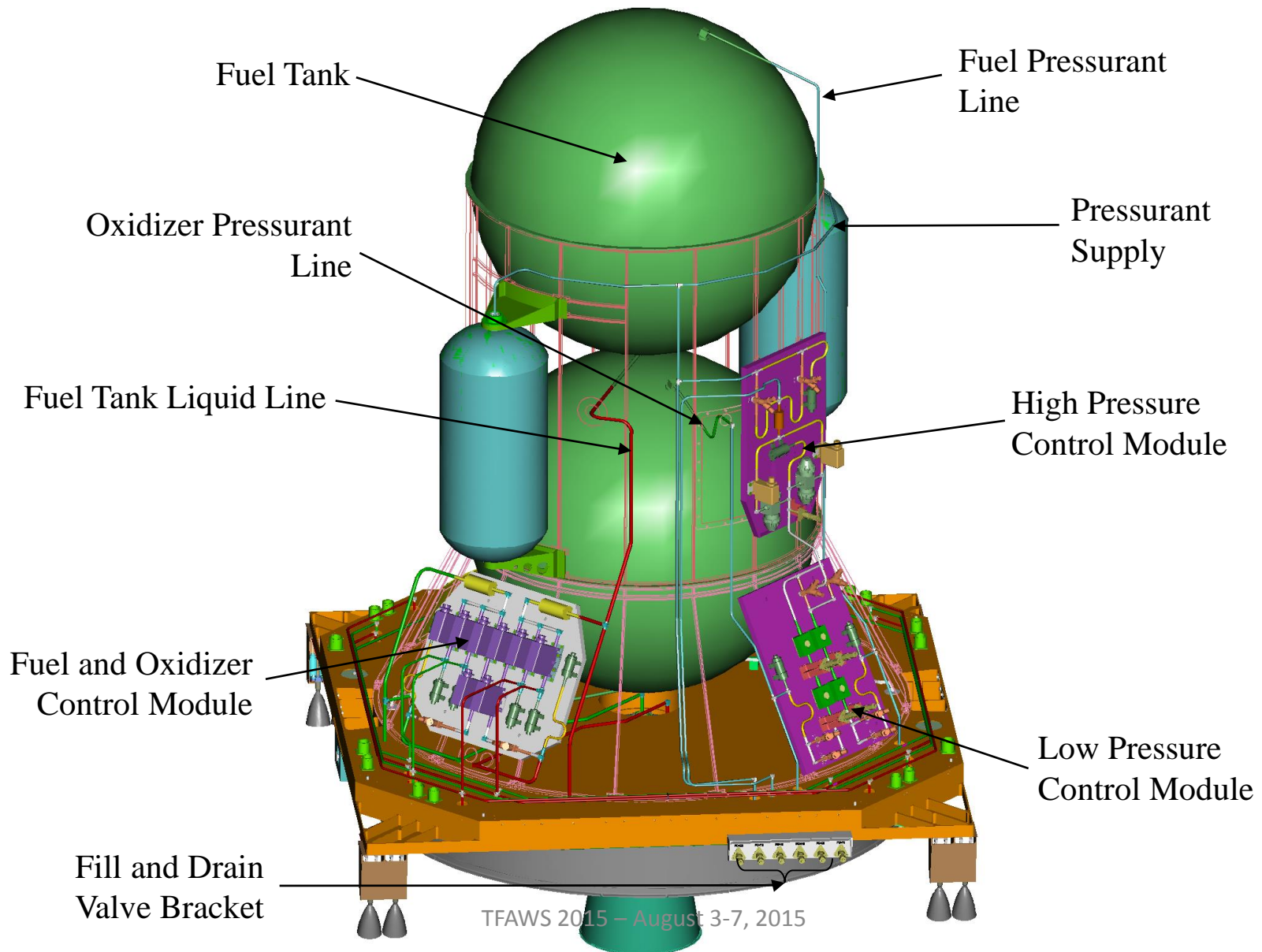
1/4" diameter tube mount shown For other options, consult factory.



Propellant Liquids

- Monoprop: Hydrazine
- Bi-Prop (Fuel + Oxidizer)
 - Monomethyl Hydrazine (MMH) is the fuel
 - Nitrogen Tetroxide (NTO) is the oxidizer
 - The freezing point can be lowered if you add nitric oxide.
 - The resulting oxidizer Mixed Oxides of Nitrogen (MON).
 - NTO has a freezing point of about -9°C
 - MON-3 (3% nitric oxide) freezes at -15°C
 - MON-25 (25% nitric oxide) freezes at -55°C

Propulsion Module Plumbing



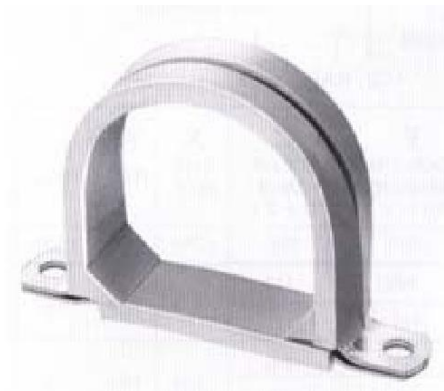
Propulsion Tanks

- Aluminum Tape
- Thermostats
- Thermistors
- Heaters
- MLI blanketing



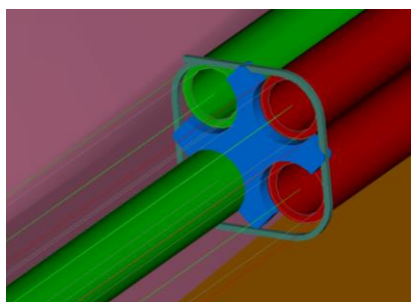
Propulsion Line Supports

- Plumbing lines are supported by thermally isolating brackets and standoffs
 - Machined Ultem 1000 Or Ultem 1200UC
 - Brackets are bonded or bolted to the primary structure
- Lines can be held with compliant clamps
 - Tefzel Cable ties may be used for off module plumbing runs – common for commercial satellites

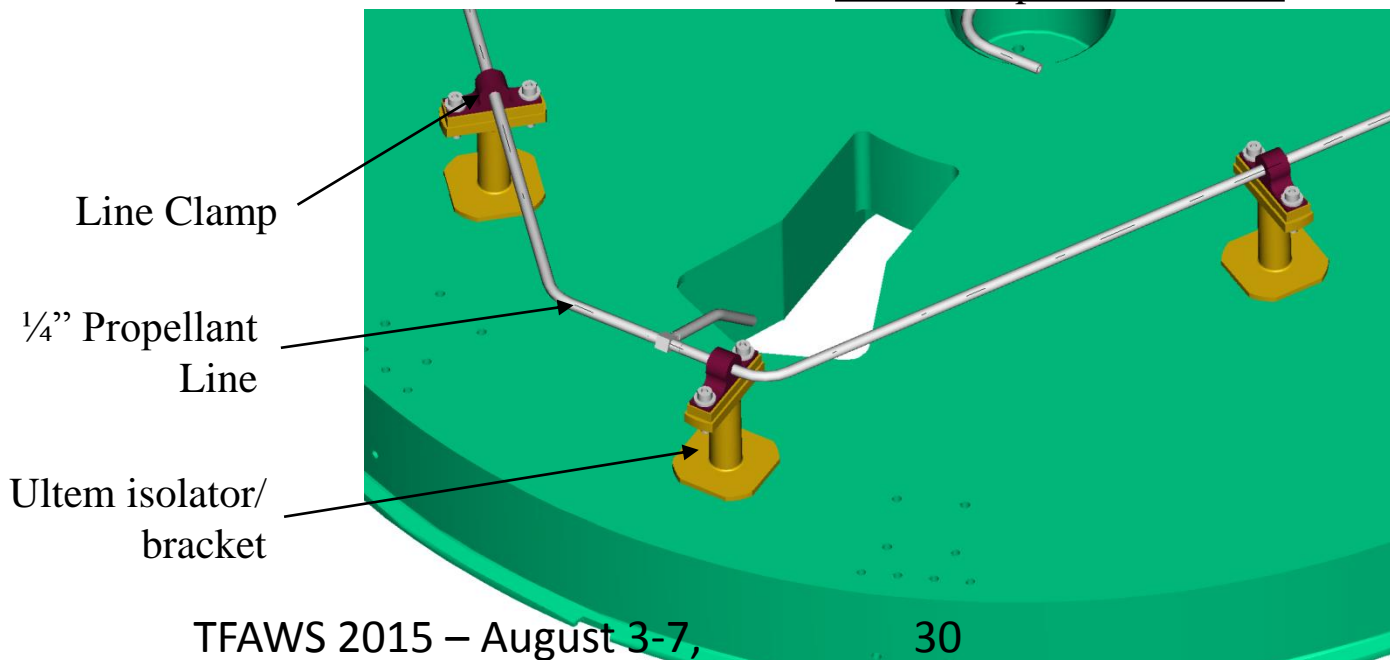


Saddle Clamp

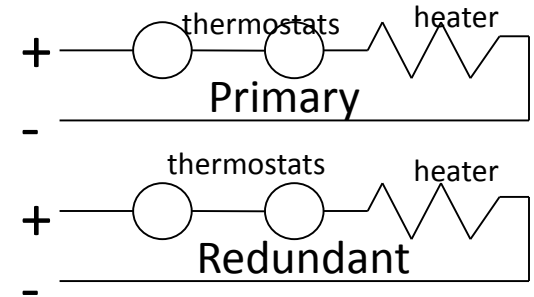
Triana Propulsion Module



“Racetrack” tube spacer and Tefzel Cable Tie

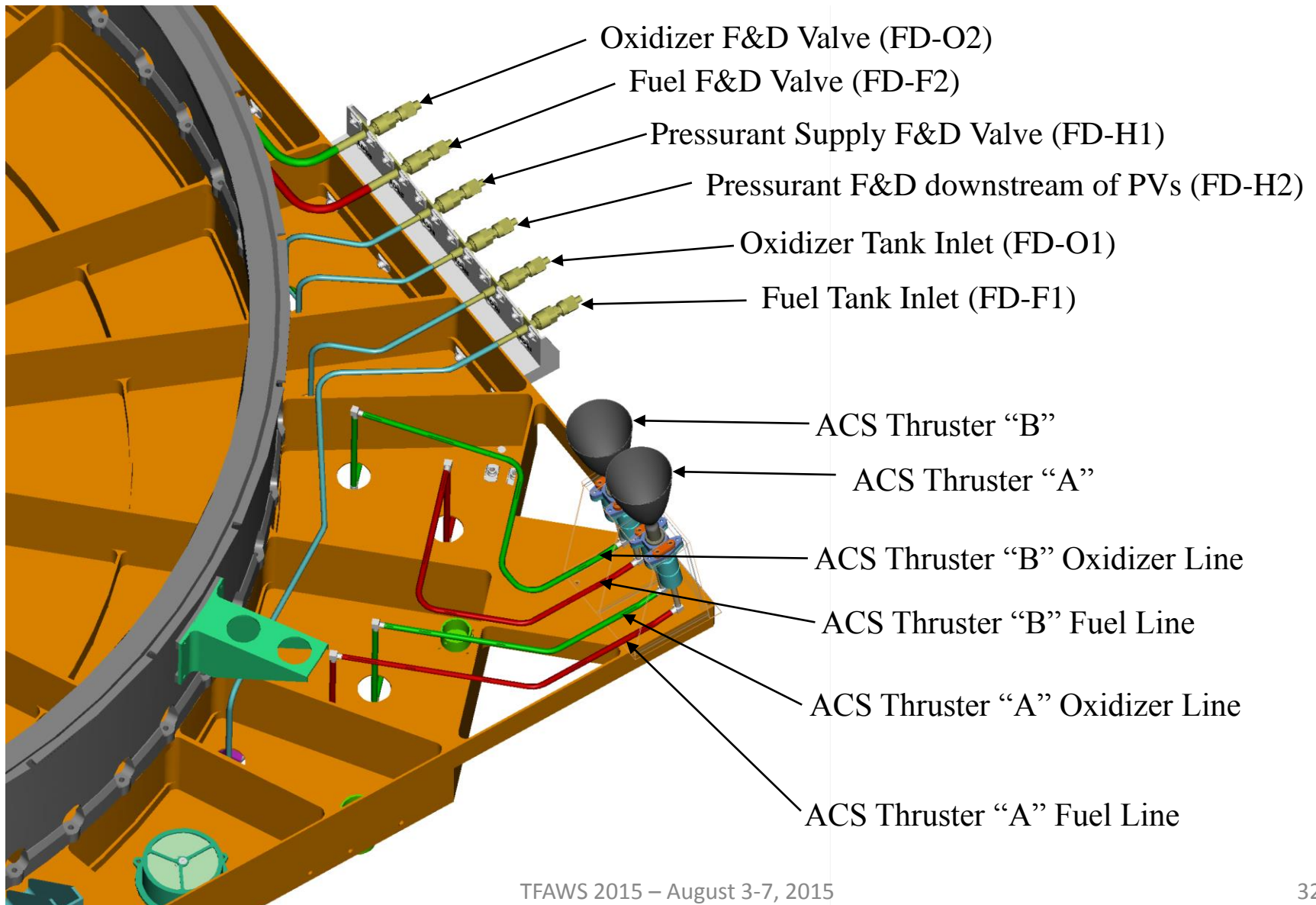


Propulsion Heaters



- Liquid Lines:
 - Entire length MLI blanketed
 - Heated with standard thermal practices
 - Dual element spiral Kapton heaters adhered with aluminum tape.
 - Two mechanical thermostats in series. Mounted in pairs on saddle blocks.
- Propellant Tanks:
 - Dual element Kapton Heaters
- Control Modules
 - Dual element Kapton patch heaters on baseplate
- Thruster Valves
 - Dual element Kapton patch heaters, mechanical thermostats.
 - Cat bed heater or chamber heater used pre-firing

Fill and Drain Valve and Thruster Plumbing



Course Summary

- Learned about “real” vs. theoretical MLI
- Learned about “Actual” thermal hardware instead of “Thermal Model” Hardware.
 - Their bonding techniques and materials.
- Learned about the special case of Propulsion Thermal.